STAFF REPORT

SUPPLY AND COST OF ALTERNATIVES TO MTBE IN GASOLINE

TECHNICAL APPENDICES

Technical Documents

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CALIFORNIA ENERGY COMMISSION

Pete Wilson, *Governor*

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Technical Documents

Prepared For:

ACUREX ENVIRONMENTAL CORPORATION
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1.0 Introduction

1.1 Parties

Purvin & Gertz, Inc., (Purvin & Gertz), was retained by Acurex Environmental Corporation (Acurex) on behalf of the California Energy Commission (CEC) to provide evaluations and assistance related to the proposed MTBE ban in California. Purvin & Gertz was retained to provide four deliverables: a presentation at a public workshop, a report on the supply costs of CARB gasoline and blend stocks from outside California, a report on the marine terminal infrastructure and associated limitations, and compilation of the final report combining Purvin & Gertz work with that of other consultants. This document is the compilation of the final report of all the consultants.

This report has been prepared for the sole benefit of the CEC. Any third party in possession of the report may not rely upon its conclusions without the written consent of Purvin & Gertz. Purvin & Gertz conducted this analysis and prepared this report utilizing reasonable care and skill in applying methods of analysis consistent with normal industry practice. All results are based on information available at the time of review. Changes in factors upon which the review is based could affect the results. Forecasts are inherently uncertain because of events or combinations of events which cannot reasonably be foreseen including the actions of government, individuals, third parties and competitors. ***NO IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE SHALL APPLY.***

Some of the information on which this report is based has been provided by others. Purvin & Gertz has utilized such information without verification unless specifically noted otherwise. Purvin & Gertz accepts no liability for errors or inaccuracies in information provided by others.
Two other consultants, Mathpro, Inc. (Mathpro) and Energy Security Analysis, Inc. (ESAI) have prepared reports on other aspects of the MTBE ban under separate contracts with Acurex which are attached to this summary. Although the goals of the work are joint, the three consultants, Purvin & Gertz, Mathpro and ESAI, are working independently and none is responsible for the work or results of another. Neither Mathpro nor ESAI is responsible for any results or opinions presented in this summary.

2.0 Summary

Three consultants have worked individually with the direction and assistance of CEC staff to prepare extensive studies of various aspects of a impacts of an MTBE ban. This summary is attached to appendices comprised of all the final reports of all the consultants. Reference is made to an Executive Summary and a Key Findings document prepared by CEC staff which presents legislative background and the design of the study as devised by CEC.

The first section of this report describes the answers sought and how the consultant reports fit together to provide the answers. None of the work of the various consultants is duplicative and all work together to provide the information required by CEC.

The ESAI report is the logical starting point of the analysis. This report reviews the alternatives to MTBE. There are other chemicals that could be used by the refining industry in lieu of MTBE to provide oxygen content in gasoline as required by regulation. ESAI has determined how much of each of the alternatives is potentially available. ESAI has also determined the cost of accessing each increment of supply of each of the alternatives.

The Purvin & Gertz reports describe the availability of CARB reformulated fuel from refineries outside California and the adequacy of the infrastructure to deliver it to the state. The cost of external supplies was determined for each major source region. Furthermore, Purvin & Gertz has provided a common pricing structure for use in all the analyses. Using a common pricing structure ensured that the results of the individual reports could be melded together.

The Mathpro reports used as inputs the Purvin & Gertz and ESAI report results. Mathpro developed a sophisticated mathematical model of the California refining industry. That model was perfected using aggregated data from the refiners that had been provided to CEC under PIIRA procedures. Then Mathpro used the mathematical model to identify all the cost elements of many alternative methods of banning MTBE. Both long term and intermediate term analyses were provided and the average cost incurred per gallon of gasoline consumed in California was determined.

3.0 Background

3.1 Goals of the Study

The fundamental goal of the study is determining how much more costly it would be to manufacture gasoline without using MTBE. Refining economics are the key to determining these costs.

There are many different ways of banning MTBE. Since legislators have many alternative ways of accomplishing an MTBE ban, the consultant studies were devised so that different possibilities could be explored. That led to all the different cases that were run by Mathpro.

If MTBE is banned, then it may be replaced by some other oxygenate compound. In this work, tertiary butyl alcohol (TBA), ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether (TAME) and ethanol were considered as oxygenate alternatives to MTBE. These four materials were chosen because all are approved by EPA and all are produced in commercial quantities already. Other oxygenates might have been considered but all the other oxygenates suffer from one flaw or another. Some are not approved by EPA so it is unclear that they would have appropriate air quality attributes. Others are not produced in commercial quantities so accessing adequate supplies would be risky. It was determined early in the process of designing this study that resources would be most wisely spent looking more intensively at prospects with few risks rather than by trying to evaluate every possible oxygenate.

Changes in the law or regulations might affect how an MTBE ban would be implemented. If federal law is changed to eliminate the oxygenate requirement, then it may be possible to produce CARB gasoline without any oxygenate. Some proposals would grant certain ethanol blends a limited vapor pressure waiver. While other regulatory changes might be envisioned, others were not evaluated in this study.

3.2 Results Sought

The results sought from the study are the increases in gasoline supply costs that would come from a ban on MTBE in each case studied. Price increases, as opposed to supply cost increases, are not directly determined by any part of the study. Some information that might be reasonably expected to lead to price impacts was identified in the study results and will be discussed below.

3.3 Components of the Solution

The three consulting firms, Purvin & Gertz, ESAI and Mathpro, each worked on separate parts of the MTBE ban problem to determine the solution. The work of the three consultants is interdependent and works together to form the whole.

ESAI determined the costs at which other the other oxygenates could be made available. Those costs, for ethanol for example, are not a single number but rather a range of numbers. There is some minimum price that must be paid to get any ethanol for the California market. At that minimum some ethanol would be available but not all ethanol supply would be provided at that price. To attract supplies from other, more costly sources, higher prices would have to be paid. ESAI worked out this relationship between the price California pays and how much oxygenate is supplied not only for ethanol but also for TBA, ETBE and TAME. ESAI's results are referred to as "supply functions", one for each oxygenate. That information is very important to Mathpro's work as will be discussed more below. One item Mathpro needed to figure out how much CARB gasoline would cost using ethanol instead of MTBE is the price of ethanol.

Purvin & Gertz determined the cost at which CARB-quality gasoline without the oxygenate blended in, known as “CARBOB”, could be made available. Similar to the work that ESAI performed, Purvin & Gertz considered all the locations from which California might access CARBOB, how much CARBOB each location might be able to provide, how much CARBOB ought to cost from each source based on 1997 prices, and how much it would cost to get it delivered to California. The result of this analysis is a supply function for CARBOB. That information also is important to Mathpro’s work.

Mathpro’s goal was to determine the lowest total cost with which the refining system as a whole could comply with any given regulation. Particularly in the intermediate cases in which the refining system could not make substantial investment due to time constraints, Mathpro needed to be able to analyze a “make or buy” decision for the refining industry in California. To do that Mathpro needed to know how much that gasoline could be acquired for from somewhere else.

Mathpro’s work is the center of the analysis. Mathpro developed a sophisticated mathematical representation of how the California refinery system works. This representation is referred to as a linear programming or LP model. LP models take advantage of tremendous computing power to determine the best way for the refining system to operate. Operating in the best way means that fuels are supplied at the lowest possible total cost.

4.0 ESAI/Oxygenate Availability Issues

ESAI has studied the availability of oxygenates including ethanol, TBA, TAME and ETBE. Their study included a review of sources and the costs of accessing supplies. Mathpro used the ESAI information to estimate the cost of adding these oxygenates to CARB gasoline.

4.1 Ethanol

Ethanol is produced mostly from biomass though other routes exist. In the U.S. corn is the most common feed stock for ethanol production. In Brazil sugarcane is more commonly used. Work is being done to develop economic processes for making ethanol from agricultural wastes like rice straw but these are not commercial. Ethanol can be made from petroleum or coal but those sources aren't significant.

There is enough ethanol produced today such that if California could access all the available supply, the state could use ethanol to provide oxygenate for all the gasoline requirements. Ethanol is produced in the U.S. mostly for consumption in states where there are tax credits or subsidies available.

California might not be able to get access to enough of the ethanol that is produced. Some of the ethanol is sold under long term contracts so getting those supplies diverted to California might not be achievable over the near term. In Brazil, most of the available ethanol is dedicated to their own ethanol fuel programs and only part of Brazil's ethanol is available for export. It isn't clear how long Brazil will have an exportable surplus. If MTBE is banned nationwide, then the rest of the nation would be interested in using ethanol to provide some or all of the required oxygen content for their gasoline.

Over the long term more ethanol could be produced. There is ample ability to grow more grain and ethanol plants could be erected in no more time than it takes to install major refinery expansions.

4.1.1 Terminal Blending

Ethanol has to be blended at the pipeline terminals, not just at the refineries. Ethanol is widely used as a gasoline component, frequently in the Midwest. Experience shows that gasoline containing ethanol cannot be shipped using the pipeline system. Water that enters the pipeline system in small amounts along with other products like diesel fuel would cause the ethanol and gasoline to separate rather than staying mixed. To overcome this problem, ethanol is blended with gasoline only when the truck is loaded to carry the gasoline-ethanol mixture to the service station.

California relies on an extensive pipeline system to distribute gasoline and few or none of the pipeline terminals have the equipment necessary to blend the ethanol with the gasoline. It would take one to two years to equip the terminals with the necessary equipment. The requirement for this equipment and the time to install it is a major factor that must be considered if ethanol is to replace MTBE.

4.2 TBA

TBA usually is manufactured as a by-product of chemical manufacturing aimed toward other goals. That kind of processing wouldn't increase under any reasonable set of price expectations. Most of the by-product TBA is converted to MTBE to maximize its value.

Some MTBE plants could be modified to manufacture TBA. The scale of the required modifications is such that they might be accomplished in the intermediate term.

The combination of diverting by-product TBA directly to California rather than to MTBE manufacturing and modifying existing MTBE plants to make TBA instead should be enough to provide adequate TBA to supply all of California's oxygenate requirements.

4.3 TAME

TAME requires amylene as a feed stock which is available in refinery streams. Amylene is not usually separated from gasoline but it is contained within some gasoline streams. A few refineries have TAME units consuming amylene that otherwise would be sold as part of gasoline but most refineries do not have such units.

Unlike ETBE, TAME cannot be manufactured in MTBE facilities. The products are too different from one another for MTBE production equipment to contribute to producing TAME.

There is only very limited TAME capacity. Over the near or intermediate terms, there is only about half enough TAME in the world to supply the oxygenate requirements for California's gasoline. Over the long term, California refineries could make some of their own TAME but combining that with all the TAME manufactured outside California would not be enough to satisfy California's requirements.

4.4 ETBE

ETBE is chemically quite similar to MTBE. One of the feed stocks for MTBE is methanol, a simple alcohol. To make ETBE, ethanol, also a simple alcohol is substituted for methanol. Getting access to enough ETBE to supply California depends on performing this substitution in MTBE production plants.

ETBE can be manufactured in only some of the facilities used to produce MTBE. There are several competing technologies for manufacturing MTBE. Some of these technologies are readily convertible to making ETBE instead although some amount of time is required. Other MTBE technologies do not lend themselves to conversion to ETBE manufacturing. There is enough MTBE manufacturing that occurs in convertible facilities so that California could be supplied with adequate ETBE by this substitution.

5.0 Purvin & Gertz/External Supply Issues

Gasoline supplied from refineries outside California could be very important if California refiners cannot manufacture adequate CARB gasoline economically without MTBE. A refiner outside the state could find it relatively easy to produce small quantities of CARB gasoline as part of his much larger business of producing whatever specifications are needed in his local marketplace. Such a refiner could "cherry pick" from among his blend stocks to find a few to make little CARB gasoline.

5.1 California's Unique Product

California's gasoline product specifications are unique and provide the state a great advantage in meeting important air quality goals. These unique specifications are a distinct disadvantage, however, when trying to find new sources of gasoline outside the state. Only four of the 725 refineries outside California have ever made CARB gasoline. California's ability to tap into distant suppliers in time of need would be much better if the gasoline they already are manufacturing was found satisfactory for the California market.

5.2 Historical Supply Patterns

California has been a self sufficient market for petroleum products for decades. A large local refining industry developed in California in the early part of the 20th century because crude oil was found in large quantities in California. California's geographical isolation from the major refining centers in the U.S. prevented them from supplying us in a cost effective way and nurtured the development of a refining industry that is sized about right to provide all the products the state needs.

Geographical and market isolation continues. There still is no pipeline to carry petroleum products into California from anywhere. Only marine transportation can be used to deliver products to California from distant suppliers.

5.3 Anticipated Supply Sources

The most important supply sources were determined to be Europe and the U.S. Gulf Coast. Other areas either are too small to be important or lack the level of refinery sophistication needed to be able to make much CARB-quality gasoline. Nevertheless some supply can come from other sources in the Middle East, Caribbean, Far East, Latin America and Pacific North West.

5.4 Potential Problem Areas

5.4 1 Jones Act Tankers

Accessing supplies from the U.S. Gulf Coast requires using Jones Act tankers. Jones Act tankers have the characteristics, among others, that they are built in U.S. shipyards and are registered in the U.S. There are relatively few Jones Act tankers, not enough to transport to California all the gasoline and blend stocks that could be produced on the U.S. Gulf Coast. No one has been identified as building new Jones Act product tankers and only two shipyards have been identified as capable of launching such vessels. The Jones Act fleet diminishes each year because of retirements, many required by federal legislation. Having enough tankers to access supplies from the U.S. Gulf Coast could be a problem.

5.4 2 Advancements in External Quality Requirements

Over time Europe and other areas around the world are advancing their own environmental product specifications. As that happens, the ability of refiners in those areas to supply California with suitable quality gasoline may be impacted. If the stringency of such specifications advances faster than refiners' ability to respond to the requirements, then their surpluses of appropriate quality for shipment here may deteriorate.

6.0 Mathpro/California Supply Issues

Mathpro incorporated supply cost information from ESAI and Purvin & Gertz into a mathematical model that Mathpro developed to determine costs of alternative cases. The ESAI information provided for Mathpro the costs of the alternative oxygenates that might be used in lieu of MTBE. The cost of imported CARBOB or alkylate provided by Purvin & Gertz allowed Mathpro to consider "make or buy" alternatives for the refining industry. Mathpro provided a great deal of information about how refineries could operate, how they might be modified to respond to various alternatives, the quality of the fuels produced and what their yield patterns would be.

Mathpro's economics results are limited to costs of supply. The total costs incurred by the petroleum industry were calculated and the result was divided by the total volume of gasoline produced. Total costs include both capital cost and operating cost. This calculation does not purport to be a price forecast but it does determine the total cost of regulatory alternatives.

The prices of petroleum products determine by whom the costs of any new regulation would be borne. If the price increase is smaller than the cost increase, then the petroleum industry would bear some of the costs while only part would be passed on to consumers. If the price increase is equal to the cost increase, then the consumer bears all the costs. If the price increase is greater than the cost increase, then the consumer would bear more than the total cost and profitability in the petroleum industry would increase. All these possibilities exist but projecting which is most likely to occur is beyond the scope of work undertaken by Mathpro.

6.1 Uses and Limitations of LP Modeling

Linear programming (LP) models are powerful mathematical tools used to analyze complex systems like oil refineries. No other mathematical tool has the potential to find reliably the best way to operate such a system. Consequently, LP models are the standard way to solve problems such as the cost of a new regulation.

LP models have certain inevitable shortcomings. The mathematics of LP models requires that relationships be represented as mathematically linear. There are many important relationships in the real world that are not linear, however. Though users of LP models like Mathpro are able through application of sophisticated techniques to portray such relationships in linear fashion, these are approximations.

LP models rely on voluminous input data to be used to "calibrate" the model. Calibration means organizing the model properly so that the model accurately portrays the behavior of the world in an actual historical period. The data needed to calibrate the model includes details of all the refinery's crude oils and other feed stocks, how each part of the refinery operated, what the capabilities are of each part of the refinery, extensive operating cost information, all the products manufactured, their exact qualities and so forth. If an LP model accurately represents what actually happened before, then it gains credibility that it will accurately portray what will happen in different circumstances in the future. Calibrations are never perfect, however, and imperfections occur because of imperfect or incomplete data describing what actually happened or because of approximations that must be made.

LP models are complicated and it is impractical due to the size of the problem to model every refinery in California separately. Furthermore, there are trade secrecy concerns that would arise if access to calibration data were to be made on a refinery by refinery basis. Instead, all the refineries are modeled together, like one big refinery. This approach allowed for access to good calibration data provided by the refiners under PIIRA and aggregated by CEC staff. A problem with this approach is that refineries can be “over-optimized” meaning that a shortcoming or constraint in one refinery can be offset by available capacity in another refinery without the modeler’s knowledge. There are ways to minimize such over-optimization which Mathpro used but it cannot be completely eliminated.

6.2 Procedure to Calibrate the Model

A data sheet was sent to each refiner in California to get calibration data for summer 1997 and on-site visits were held with every refining company for them to explain their operations. The data sheets were returned to CEC and the data was aggregated together to preserve trade secrecy and comply with the requirements of PIIRA. The aggregated data was provided to Mathpro for use in the calibration.

Mathpro prepared a model of summertime 1997 conditions. Summertime was chosen because that is when demand for gasoline is greatest and when the load on the refining industry is highest. Summer of 1997 was chosen because summer 1998 was still in the future when this process occurred. Summer 1996 was not chosen because refiners learned a lot about how to make CARB gasoline between spring of 1996 when the program first was introduced and summer of 1997. In the summer of 1996 the refiners did as well as they could do at that time but since the CARB program is complicated, it took a while to figure out the best ways to respond to it.

Mathpro prepared their calibration case and sent it back to CEC and the refining industry for comments. Based on comments received back, an improved calibration case was developed that was finally adopted for use in the study.

6.3 Results of the Analysis

Mathpro’s model was used to determine the cost of various regulatory alternatives. The most important cases were those involving ethanol, TBA, ETBE, no oxygenates and mixed oxygenates. There are variants involving treatment of tax credits and other matters which are viewed as interesting but less critical.

Mathpro ran the model to simulate the refining industry continuing to make other products like CARB diesel needed by California and doing its best to manufacture CARB gasoline also. In many cases trade was needed either to supplement CARB gasoline supplies or to dispose of gasoline components that does not meet the CARB specifications. Trade was allowed in jet fuel or EPA diesel but not in CARB diesel, the source of which would be uncertain.

Mathpro’s results include certain key items. These include how much of each product is manufactured by the California industry, the trade in products and intermediates that is needed, how much of various kinds of refinery capacity must be built in the long term cases, and what the average cost increase is that is attributable to the case..

6.4 Intermediate Term Issues

Intermediate term cases as a group show substantial trade both inbound and outbound. The cases with the most trade are the No Oxygenate cases and the Ethanol cases. The presence of large volumes of trade in these cases should be interpreted as meaning the challenges posed by meeting the predictive model without using oxygenates or with using ethanol in lieu of MTBE are large. Conversely, the absence of substantial trade increases in other cases is indicative that the California refining industry would have less difficulty complying with those cases.

In the No Oxygenate cases 300-400 thousand barrels per day of finished product or blend stock imports are required. In the Ethanol cases about 200-300 thousand barrels of imports are more typical. TBA and ETBE as well as the mixed oxygenate cases showed only limited import volume, 50 thousand barrels per day or less.

Similarly, the No Oxygenate and Ethanol cases generally required the refining industry to dispose of substantial rejected blend stocks. These are gasoline components whose properties do not fit into CARB gasoline very well. Currently such materials are incorporated into gasoline because some other materials offset their negative qualities. The No Oxygenate case had particularly high rejected blendstocks, about 150-200 thousand barrels per day. The Ethanol cases were better in this respect rejecting generally 50-100 thousand barrels per day. As in the case of imports, TBA, ETBE and mixed oxygenate cases all showed little or no rejected blend stocks.

6.5 Long Term Issues

Long term cases show that the refining industry's appetite for imports will continue and the lowest overall cost of supplying California would be achieved by importing substantial parts of the state's gasoline. Import volumes are substantially lower than the intermediate term cases showing about 150-200 thousand barrels per day for the No Oxygenate cases and 90-130 thousand barrels per day in the Ethanol cases. The TBA cases imported small amounts of alkylate for gasoline blend stock and the ETBE and mixed oxygenates had no increase in imports over the current situation.

The major difference between the intermediate term and long term cases is a substantial reduction in the amount of rejected blend stocks. Through investment available only in the long term, refiners would be able to use most of the blend stocks and reject comparatively little.

Mathpro has not evaluated a set of Ethanol and No Oxygenate long term cases that do not involve import increases. The costs attributable to such cases would have to be higher than the cases Mathpro presented because if they were lower Mathpro would have presented these results instead of the ones shown.